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TECHNICAL MEMORANDUM X-912

DYNAMIC-STABILITY CHARACTERISTICS OF MODELS OF PROPOSED APOLLO CONFIGURATIONS AT MACH NUMBERS FROM 0.30 TO 1.20

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DYNAMIC-STABILITY CHARACTERISTICS OF MODELS OF PROPOSED APOLLO CONFIGURATIONS AT MACH NUMBERS FROM 0.30 TO 1.20*

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SUMMARY

Wind-tunnel measurements of some of the dynamic-stability characteristics of 0.055-scale models of proposed Apollo launch-escape and command-module configurations (identified as $E_4T_{12}C$ and C, respectively) have been made at Mach numbers from 0.30 to 1.20 by using a small-amplitude forced-oscillation technique. The amplitude of oscillation was 2°. The damping and oscillatory-stability parameters were measured in pitch for configuration $E_4T_{12}C$ and configuration C with heat shield aft and in a reentry attitude. The damping and oscillatory-stability parameters were also measured in yaw for configuration C in a reentry attitude. The investigation was made at angles of attack likely to be encountered during the several phases of flight. Because of tunnel-size and balance-load limits, the size of the models was restricted and the centers of oscillation were not coincident with the proposed center-of-mass locations for configuration $E_4T_{12}C$ and configuration C in a reentry attitude.

Configuration $E_4T_{12}C$ displayed large changes in the oscillatory-stability and damping-in-pitch parameters with angle of attack and Mach number. The damping parameter was near zero at angles of attack of about 0° but decreased to large negative values at angles of attack greater than about 3°; whereas, the oscillatory-stability parameter generally was negative around zero angle of attack but became positive for angles of attack greater than about 3°. The presence of a dummy balance cover on the apex of the command module had no significant effect on either the damping or stability parameter.

For configuration C with heat shield aft, the values of the damping and oscillatory-stability parameters in pitch were nearly independent of angle of attack and Mach number. The characteristics of configuration C in a reentry attitude were dependent on angle of attack, Mach number, and Reynolds number. At the higher angles of attack, the oscillatory-stability parameter was negative and the damping parameter was positive. At the lower angles of attack, the oscillatory-stability parameter was positive and the damping parameter was negative. Appreciable differences in the oscillatory-stability and damping parameters were measured for the different oscillation-center locations.

For configuration C in a reentry attitude, the oscillatory-directional-stability parameter was positive and the damping-in-yaw parameter was near zero or positive at all Mach numbers.

*Title, Unclassified.

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INTRODUCTION

A research program is being conducted by the National Aeronautics and Space Administration to determine the aerodynamic characteristics of proposed configurations of the Project Apollo vehicle, a manned lunar-exploration spacecraft. Wind-tunnel measurements of the static longitudinal aerodynamic characteristics of 0.07-scale models of proposed configurations of the Project Apollo vehicle are presented for Mach numbers from 1.57 to 4.65 in reference 1, and from Mach numbers of 0.30 to 1.20 in reference 2. Reference 3 presents some of the dynamic-stability characteristics of the proposed Apollo vehicles designated $ET_{12}C$, $E_4T_{12}C$, and C at Mach numbers from 2.40 to 4.65.

This paper presents without detailed analysis some of the dynamic-stability characteristics of configurations $E_4T_{12}C$ and C as obtained in the Langley 8-foot transonic pressure tunnel at Mach numbers from 0.30 to 1.20. The dynamic-stability characteristics in pitch of the launch-escape configuration $E_4T_{12}C$ and the command module C with heat shield aft and in a reentry attitude were measured. In addition, the dynamic-stability characteristics in yaw for the command module C in a reentry attitude were measured.

Because of tunnel-size and balance-load limits, the size of the models was restricted and the centers of oscillation were not coincident with the proposed center-of-mass locations for the model of the launch-escape configuration and the model of the command module in a reentry attitude. The effect of changes in the position of the oscillation center of the model of the reentry configuration was investigated. In an effort to determine the effect of Reynolds number on the stability characteristics, the investigation was conducted over a range of Reynolds number from 0.62×10^6 to 3.49×10^6. The data are presented for the angle-of-attack ranges likely to be encountered during the several phases of flight.

SYMBOLS

The aerodynamic coefficients are referred to the body system of axes originating at the oscillation centers of the models, as shown in figure 1. The equations used to obtain the nondimensional aerodynamic parameters can be found in reference 3.

A reference area, $\pi\left(\frac{d}{2}\right)^2$, 0.3912 sq ft

d reference length, maximum diameter of model, 0.7058 ft

f frequency of oscillation, cps

k reduced-frequency parameter, $\omega d/V$, radians

M free-stream Mach number

q pitching velocity, radians/sec

q_∞ free-stream dynamic pressure, lb/sq ft

R Reynolds number based on d

r yawing velocity, radians/sec

V free-stream velocity, ft/sec

α mean angle of attack, deg or radians

β angle of sideslip, radians

ω angular velocity, $2\pi f$, radians/sec

C_m pitching-moment coefficient, $\dfrac{\text{Pitching moment}}{q_\infty Ad}$

C_n yawing-moment coefficient, $\dfrac{\text{Yawing moment}}{q_\infty Ad}$

$C_{m_\alpha} = \dfrac{\partial C_m}{\partial \alpha}$ per radian

$C_{m_q} = \dfrac{\partial C_m}{\partial\left(\dfrac{qd}{V}\right)}$ per radian

$C_{n_\beta} = \dfrac{\partial C_n}{\partial \beta}$ per radian

$C_{n_r} = \dfrac{\partial C_n}{\partial\left(\dfrac{rd}{V}\right)}$ per radian

$C_{m_{\dot\alpha}} = \dfrac{\partial C_m}{\partial\left(\dfrac{\dot\alpha d}{V}\right)}$ per radian

$C_{m_{\dot q}} = \dfrac{\partial C_m}{\partial\left(\dfrac{\dot q d^2}{V^2}\right)}$ per radian

$$C_{n_{\dot{\beta}}} = \frac{\partial C_n}{\partial\left(\frac{\dot{\beta} d}{V}\right)} \quad \text{per radian}$$

$$C_{n_{\dot{r}}} = \frac{\partial C_n}{\partial\left(\frac{\dot{r} d^2}{V^2}\right)} \quad \text{per radian}$$

$C_{m_q} + C_{m_{\dot{\alpha}}}$ damping-in-pitch parameter, per radian

$C_{m_\alpha} - k^2 C_{m_{\dot{q}}}$ oscillatory-longitudinal-stability parameter, per radian

$C_{n_r} - C_{n_{\dot{\beta}}} \cos \alpha$ damping-in-yaw parameter, per radian

$C_{n_\beta} \cos \alpha + k^2 C_{n_{\dot{r}}}$ oscillatory-directional-stability parameter, per radian

(The expression $\cos \alpha$ appears in the damping-in-yaw and oscillatory-directional-stability parameters because these parameters are expressed in the body system of axes.)

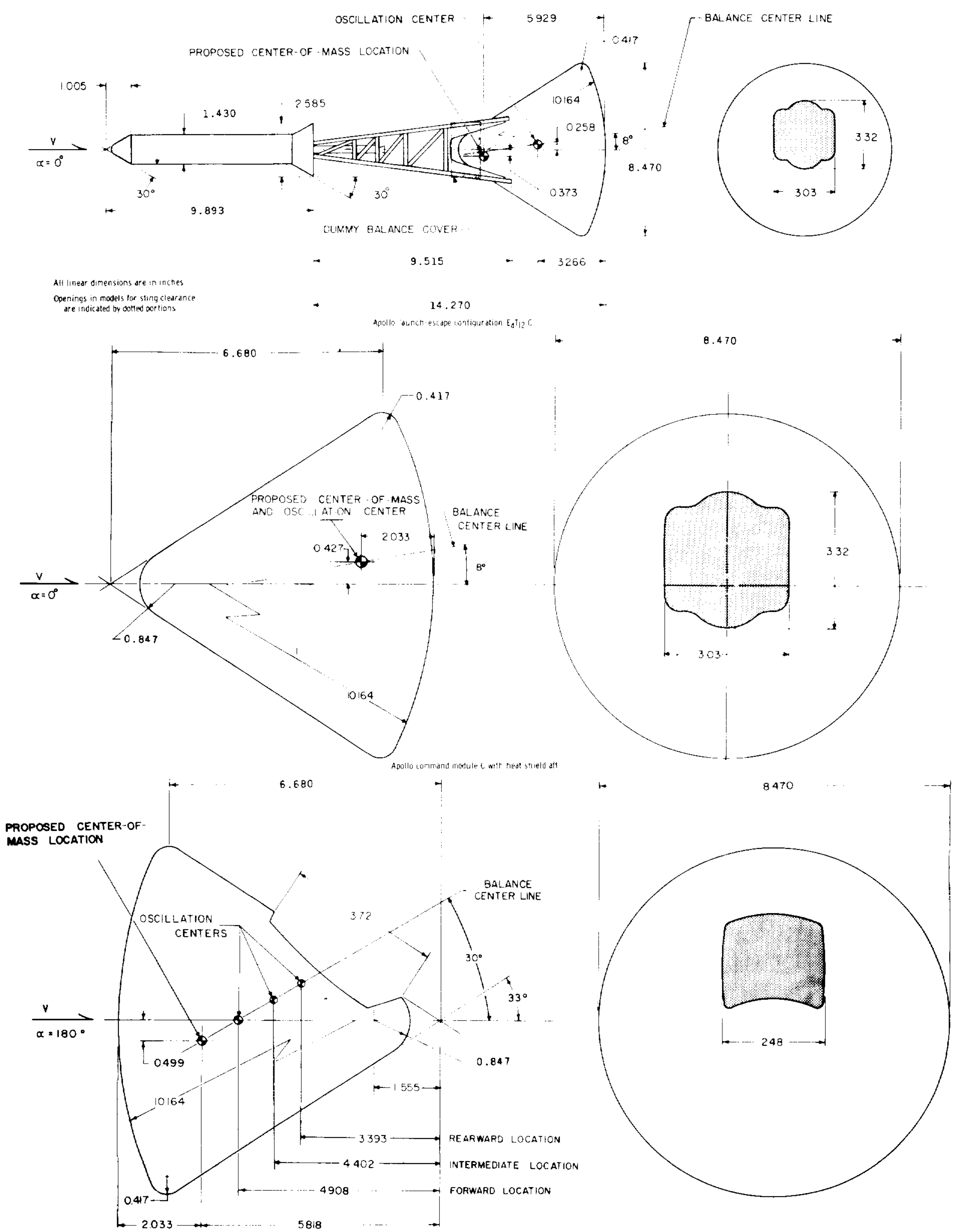
A dot over a quantity denotes a derivative with respect to time.

MODELS

Design dimensions of the 0.055-scale models of the proposed Apollo launch-escape configuration $E_4T_{12}C$ and of the command module C are shown in sketch a. The designations used were assigned by the prime contractor for Apollo to facilitate identification of various configurations under investigation. The letters are associated with the component parts as follows: E is for the escape rocket, T is for the tower, and C is for the command module. Numbered subscripts refer to specific versions of each component.

The models were made of aluminum, with the escape-rocket tower made of steel and the escape-rocket motor made of magnesium and plastic-impregnated fiber glass. The model surfaces exposed to the airstream were aerodynamically smooth. The openings in the models necessary for sting clearance are shown in sketch a.

Because of tunnel-size and balance-load limits, the size of the models was restricted and the centers of oscillation were not coincident with the proposed center-of-mass locations for the model of the launch-escape configuration and the model of the command module in a reentry attitude. Since the oscillation center could not be located at the proposed center of mass of the model of the command module in a reentry attitude, spacers were used between



Apollo launch-escape configuration $E_4T_{12}C$

Apollo command module C with heat shield aft

Apollo command module C in a reentry attitude

Sketch a

the model and oscillation balance for some tests so that the oscillation center could be moved farther from the proposed center-of-mass location to provide a qualitative indication of the effect of oscillation-center location on the measured values of the dynamic-stability characteristics. No attempt was made to show this effect for the launch-escape configuration.

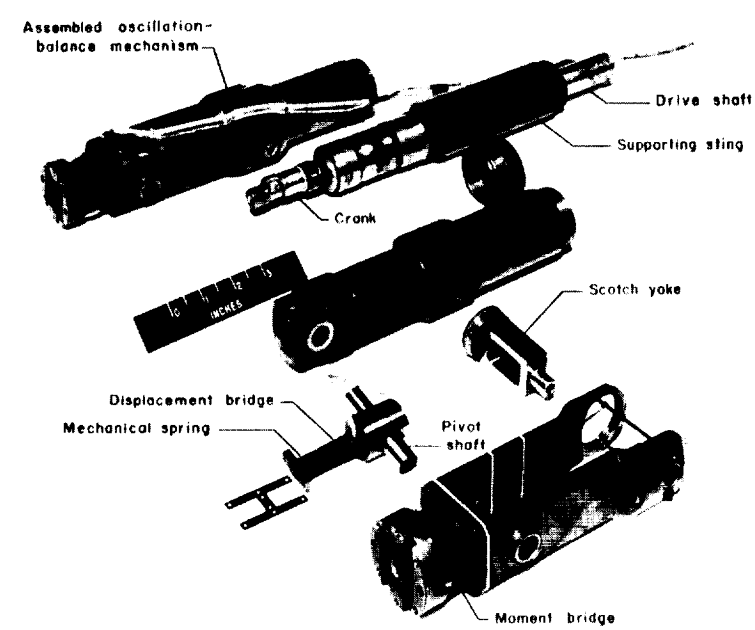
A small circular cylinder was fitted to the apex of the command module of the model of the launch-escape configuration for several tests to simulate an extended balance cover which might be used for possible future tests of the configuration with the balance moved forward to place the oscillation center at the proposed center-of-mass location.

TUNNEL

The investigation was made in the Langley 8-foot transonic pressure tunnel, which is a single-return, closed-circuit tunnel. The upper and lower walls of the test section are slotted to permit continuous operation through the transonic speed range. The Mach number in the test section can be continuously varied from a low subsonic value to 1.20. The sting-support system is so designed as to keep the center of oscillation of the model near the center line of the tunnel through a range of angle of attack from -5° to 14° when used in conjunction with the oscillation-balance mechanism.

APPARATUS AND PROCEDURE

The models were mounted on an oscillation-balance mechanism. Exploded and assembled views of its forward portion are shown in the following photograph:



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The oscillation-balance mechanism consists of a two-component strain-gage balance which is rigidly forced to perform a single-degree-of-freedom angular oscillation. The rotary motion of an amplidyne-controlled motor is used to give the essentially sinusoidal oscillatory motion to the balance through a crank and Scotch yoke mechanism. The frequency of oscillation can be varied from about 0 to 25 cycles per second. A mechanical spring is mounted inside the oscillation balance in such a way that the test model is connected to ground (the supporting sting) through the spring as well as through the strain-gage beams of the oscillation balance. The mechanical spring has mounted to it a wire-strain-gage bridge which provides an output proportional to model displacement with respect to the fixed sting.

Dynamic data are obtained from the oscillation balance by alternating-current strain-gage bridges which sense the instantaneous torque required to drive the model and the instantaneous angular displacement of the model with respect to the sting. These strain-gage bridges modulate 3,000-cycle carrier voltages which are passed through coupled electrical sine-cosine resolvers that rotate at the frequency of oscillation of the model. The resolvers divide the signals into orthogonal components, which are then demodulated and read on damped digital voltmeters. By responding only to signals at the fundamental frequency of oscillation, the resolver—damped-voltmeter system performs the desirable function of eliminating the effects of random torque inputs due to airstream turbulence or buffeting. The maximum torque required to drive the model, the maximum displacement of the model with respect to the sting, and the phase angle between torque and displacement are found from the orthogonal components of torque and displacement. The frequency of oscillation is obtained by counting pulses generated by an induction-coil pickup and a 100-tooth gear fastened to the shaft of one of the resolvers. The damping and spring-inertia characteristics are then computed from the measured values of torque, displacement, phase angle, and frequency.

All data were taken with the model oscillating near its velocity-resonance frequency, since this condition results in greater accuracy in determining the model damping and stability characteristics. A detailed discussion of this technique of measuring the dynamic-stability characteristics of models is given in reference 4.

PRESENTATION OF DATA

The investigation was made at Mach numbers from 0.30 to 1.20 by using a small-amplitude forced-oscillation technique. The amplitude of the model oscillations was 2°. Reynolds number, based on the maximum diameter of the model, varied from 0.62×10^{6} to 3.49×10^{6}. The upper values of the Reynolds number were dictated by the load limits of the oscillation balance. The data were taken for angles of attack likely to be encountered during the several phases of flight.

The basic dynamic-stability data obtained in this investigation are presented in the following figures:

Configuration	M	R	α, deg	Figure
		Longitudinal		
$E_4T_{12}C$ (launch-escape)	0.30	2.50×10^6	-8 to 0	1(a)
	.70	3.49	-4 to 4	1(b)
	.70	.62	-12 to 6	1(b)
	.90	2.78	-5 to 4	1(c)
	1.00	2.88	-5 to 3	1(d)
	1.00	.72	-12 to 6	1(d)
	1.20	2.96	-6 to 5	1(e)
	1.20	.75	-12 to 6	1(e)
C (command module), heat shield aft	0.30	2.50×10^6	-12 to 6	2(a)
	.70	3.49	↓	2(b)
	.90	2.78		2(c)
	1.00	2.88		2(d)
	1.20	2.96		2(e)
C (command module), reentry attitude	0.30	2.50×10^6	136 to 154	3(a)
	.70	3.49	↓	3(b) and 4(a)
	.70	.62		3(b)
	.90	2.78		3(c)
	1.00	2.88		3(d) and 4(b)
	1.00	.72		3(d)
	1.20	2.96		3(e) and 4(c)
	1.20	.75		3(e)
		Directional		
C (command module), reentry attitude	0.30	2.50×10^6	136 to 154	5(a)
	.70	3.49	↓	5(b)
	.90	2.78		5(c)
	1.00	2.88		5(d)
	1.20	2.96		5(e)

SUMMARY OF RESULTS

A detailed analysis of the dynamic-stability characteristics of models of proposed Apollo configurations $E_4T_{12}C$ and C has been omitted. However, some of the more important results are summarized. As previously mentioned, the oscillation centers were not coincident with the proposed center-of-mass locations for the model of the launch-escape configuration and the model of the command module in a reentry attitude. Therefore, the data are strictly applicable only for the geometry and oscillation centers used.

As seen in figure 1, the model of the launch-escape configuration $E_4T_{12}C$ displayed large changes in the oscillatory-longitudinal-stability and damping-in-pitch parameters with mean angle of attack and Mach number, particularly near $\alpha = 0^{\circ}$. In general, the damping parameter was near zero at $\alpha \approx 0^{\circ}$ but decreased to large negative values at angles of attack greater than about 3°. Except at $M = 0.30$, the oscillatory-stability parameter was negative at $\alpha \approx 0^{\circ}$ but rapidly increased to large positive values at angles of attack greater than about 3°. This combination of strong positive increases in the stability parameter accompanied by large negative changes in the damping parameter is typical and has been measured for many different models; an example can be seen in reference 5. Similar trends of the stability and damping parameters were also measured for this model at Mach numbers from 2.40 to 4.65 in the investigation presented in reference 3. Large changes in Reynolds number did not significantly affect the measured parameters except at $M = 1.00$. The presence of the dummy balance cover on the apex of the command module had no significant effect on either the damping or the stability parameter.

For the model of the command module C with heat shield aft, the values of the damping-in-pitch and oscillatory-stability parameters were essentially independent of both angle of attack and Mach number, except at the lower Mach numbers. (See fig. 2.)

As shown in figure 3, the characteristics of the model of the command module C in a reentry attitude were dependent on mean angle of attack, Mach number, and Reynolds number. The oscillatory-stability parameter was positive at the lower angles of attack and became negative at the higher angles of attack. The damping-in-pitch parameter was zero or negative at the lower angles of attack and became positive at the higher angles of attack.

Figure 4 shows the effect of oscillation-center location on the characteristics of this configuration. Appreciable nonlinear changes in the damping-in-pitch and oscillatory-stability parameters were measured at the different oscillation-center locations. The oscillatory-stability parameter, however, was more negative at the forward oscillation center, as would be expected, and the trends indicate that the stability parameter would remain negative through a greater range of angle of attack at the more forward proposed center-of-mass location. Although the measured damping was quite erratic, the trends, especially at $M = 1.20$, indicate that the greatest negative values of the damping-in-pitch parameter would occur at the forward oscillation center nearest the proposed center-of-mass location.

For the model of the command module C in a reentry attitude, the oscillatory-directional-stability parameter was positive (indicating positive trim stability) and the damping-in-yaw parameter was near zero or positive at all Mach numbers. (See fig. 5.) The damping-in-yaw parameter and the oscillatory-directional-stability parameter showed only slight dependence on mean angle of attack and Mach number.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., November 20, 1963.

REFERENCES

1. Morgan, James R., and Fournier, Roger H.: Static Longitudinal Aerodynamic Characteristics of a 0.07-Scale Model of a Proposed Apollo Spacecraft at Mach Numbers of 1.57 to 4.65. NASA TM X-603, 1961.

2. Pearson, Albin O.: Wind-Tunnel Investigation of the Static Longitudinal Aerodynamic Characteristics of Models of Reentry and Atmospheric-Abort Configurations of a Proposed Apollo Spacecraft at Mach Numbers From 0.30 to 1.20. NASA TM X-604, 1961.

3. Kilgore, Robert A., and Averett, Benjamin T.: Wind-Tunnel Measurements of Some Dynamic Stability Characteristics of 0.055-Scale Models of Proposed Apollo Command Module and Launch-Escape Configurations at Mach Numbers From 2.40 to 4.65. NASA TM X-769, 1963.

4. Braslow, Albert L., Wiley, Harleth G., and Lee, Cullen Q.: A Rigidly Forced Oscillation System for Measuring Dynamic-Stability Parameters in Transonic and Supersonic Wind Tunnels. NASA TN D-1231, 1962. (Supersedes NACA RM L58A28.)

5. Kilgore, Robert A., and Hayes, William C., Jr.: Transonic Wind-Tunnel Measurements of the Damping in Pitch and Oscillatory Longitudinal Stability of Several Reentry Vehicles Having Low Lift-Drag Ratios. NASA TM X-609, 1961.

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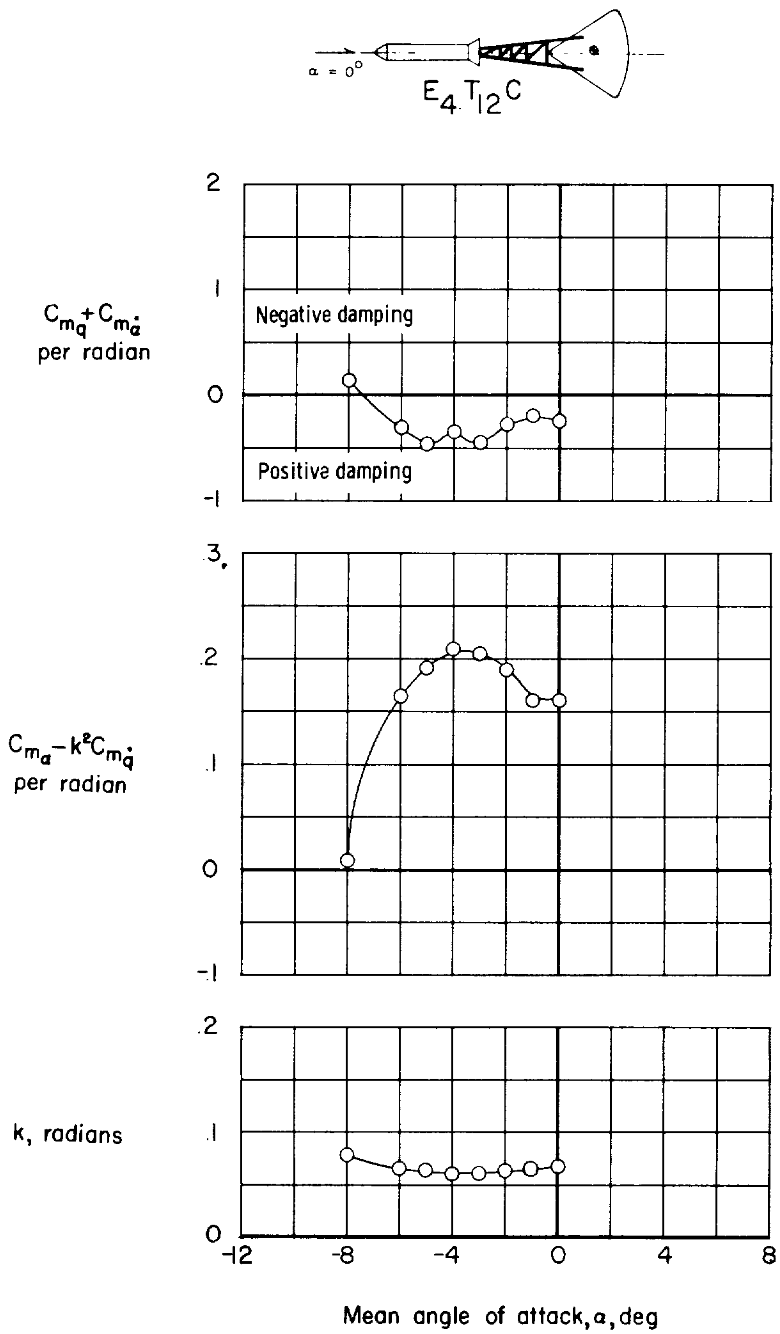

(a) M = 0.30; R = 2.50 × 10^6.

Figure 1.- Variation of damping-in-pitch parameter, oscillatory-longitudinal-stability parameter, and reduced-frequency parameter with mean angle of attack for model of launch-escape configuration $E_4T_{12}C$.

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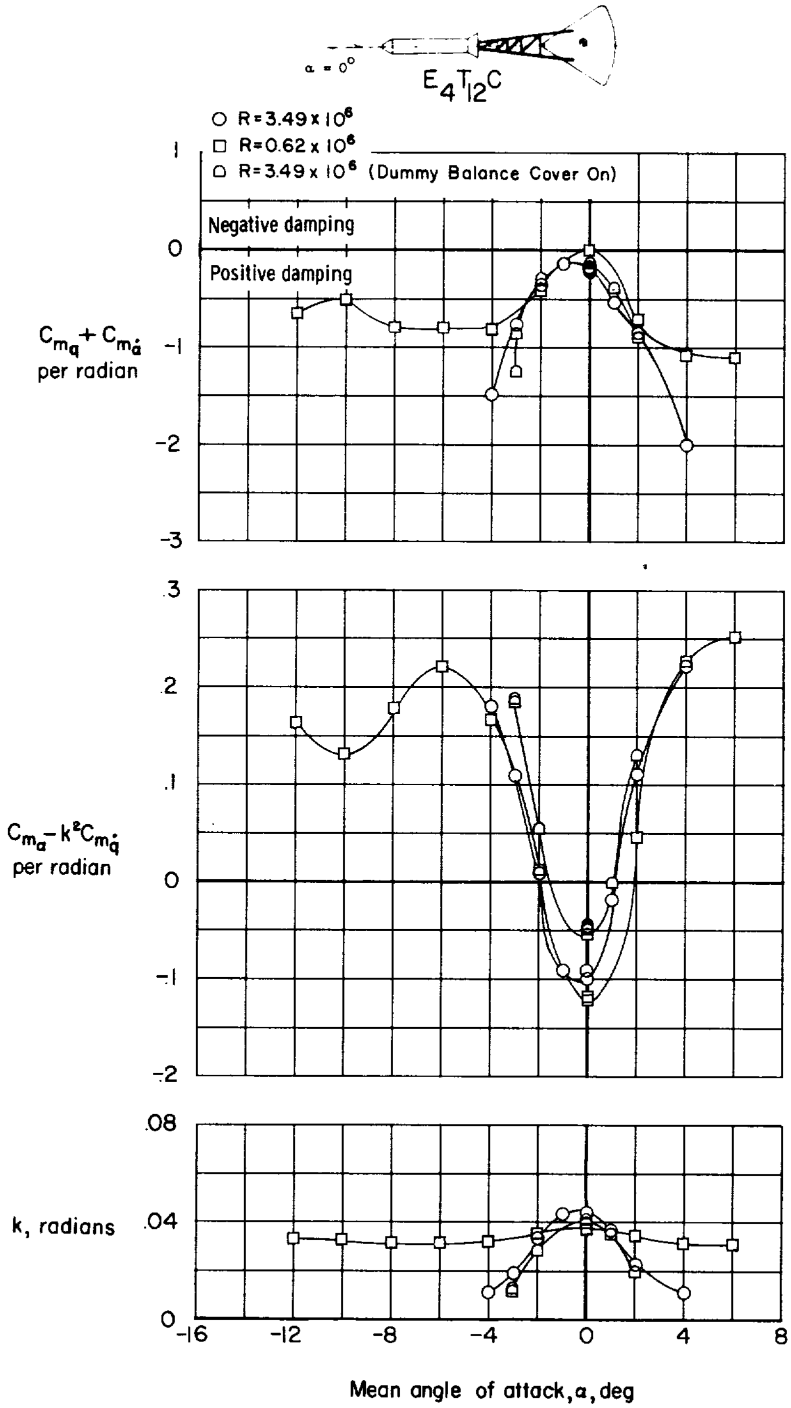

(b) M = 0.70.

Figure 1.- Continued.

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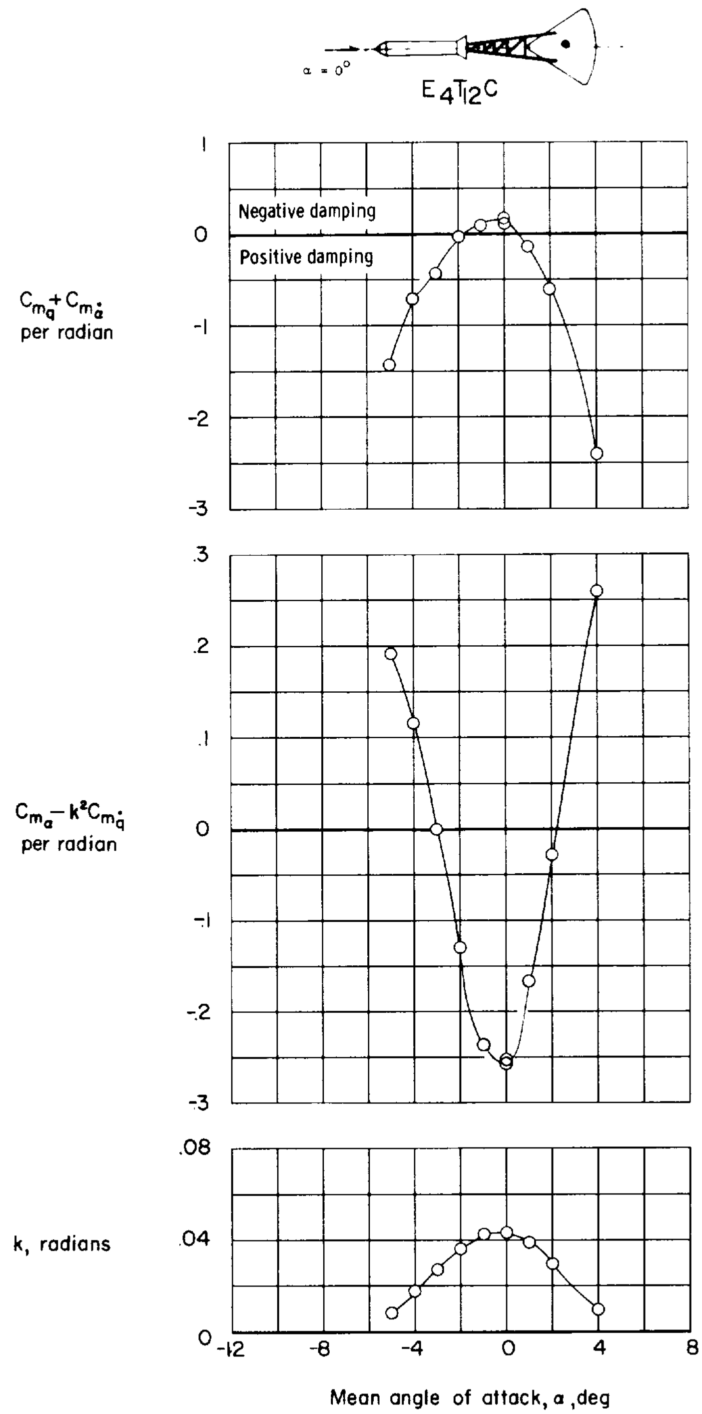

(c) M = 0.90; R = 2.78 x 10^6.

Figure 1.- Continued.

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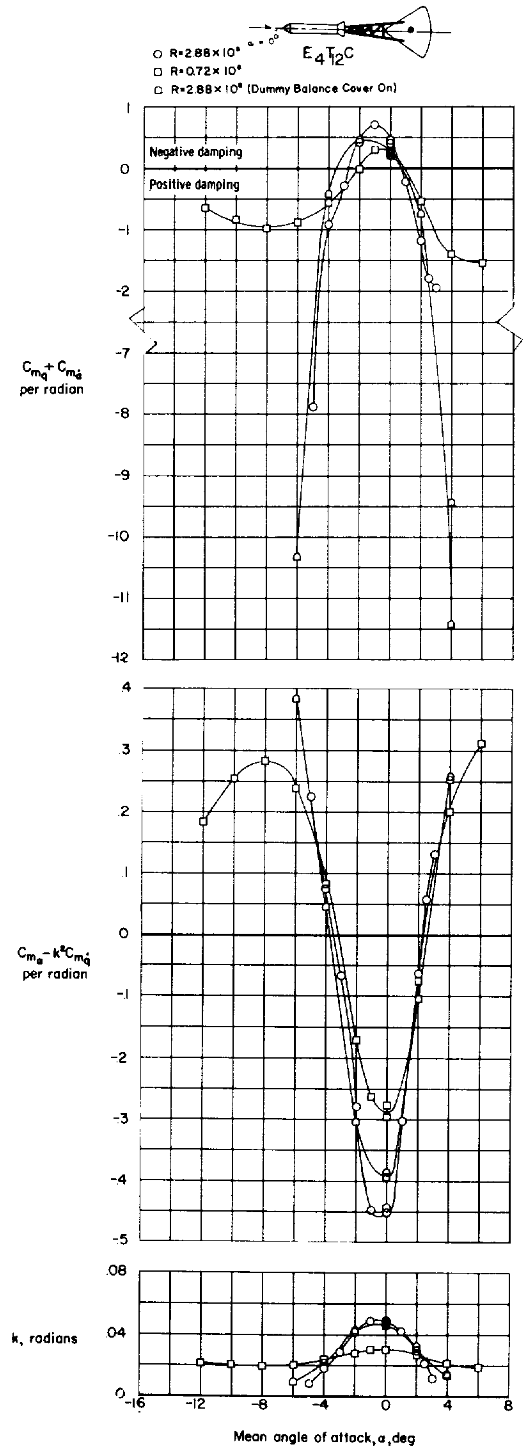
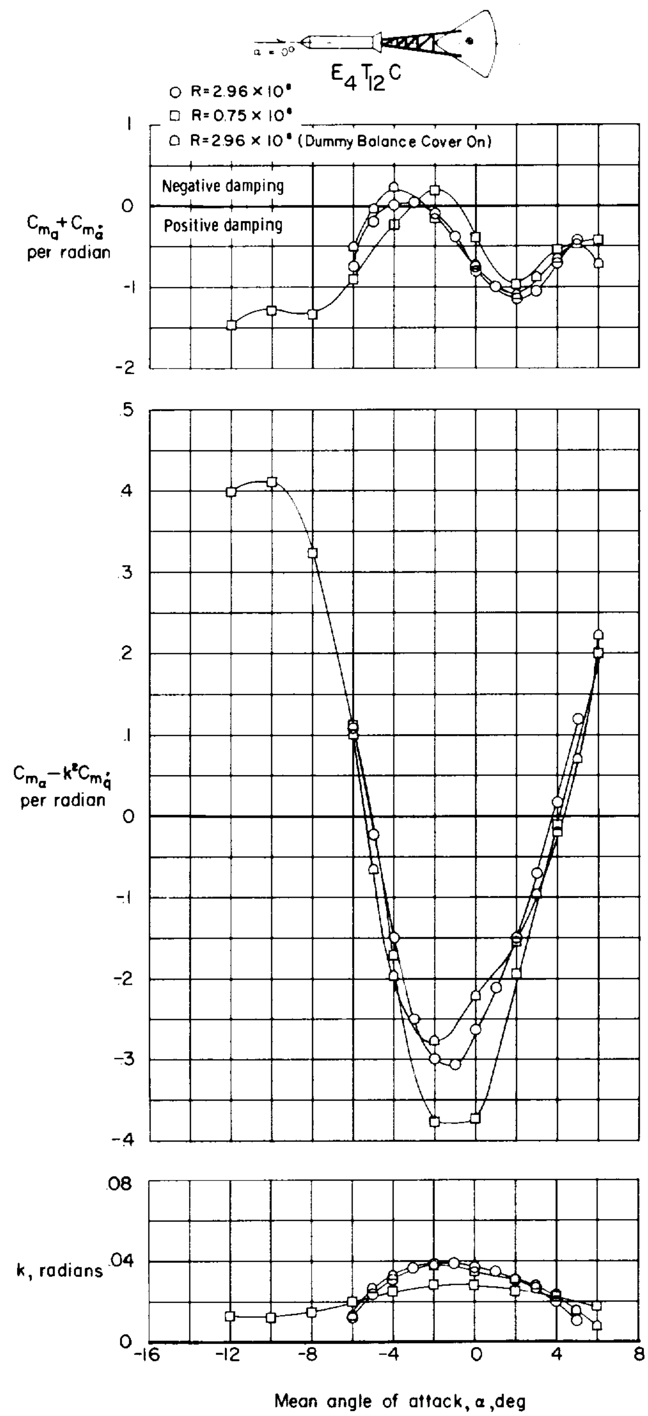


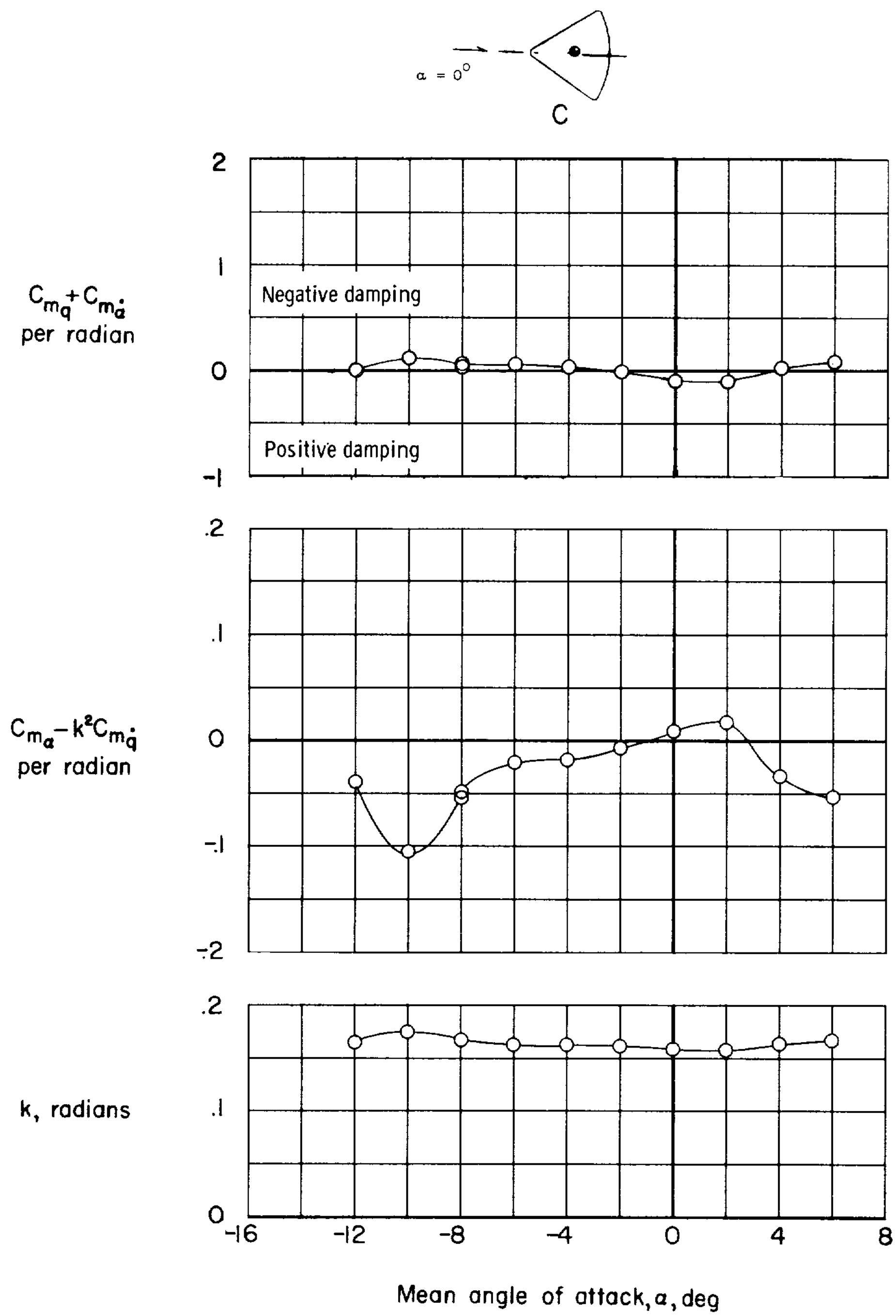
(d) $M = 1.00$.

Figure 1.- Continued.



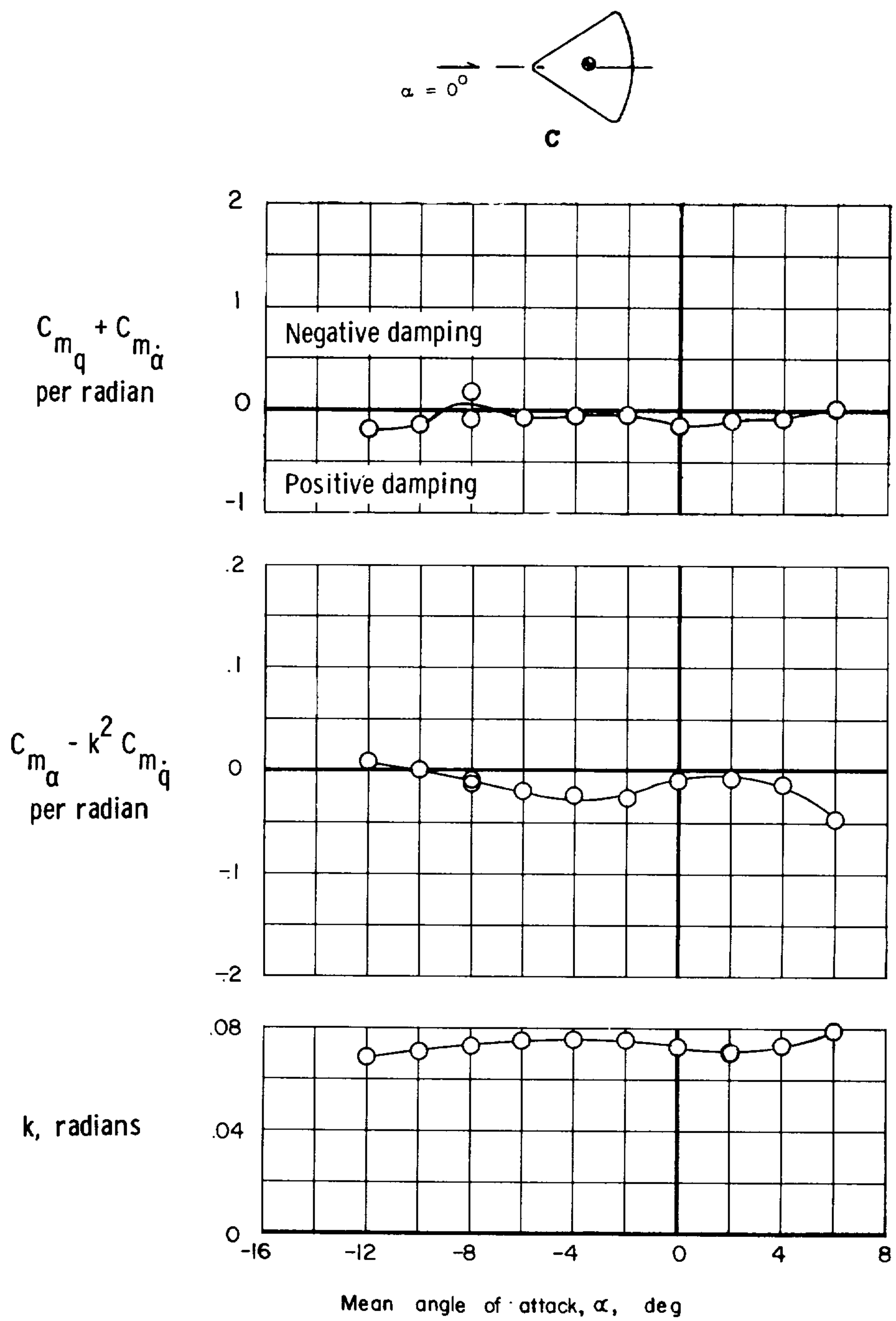
(e) M = 1.20.

Figure 1.- Concluded.



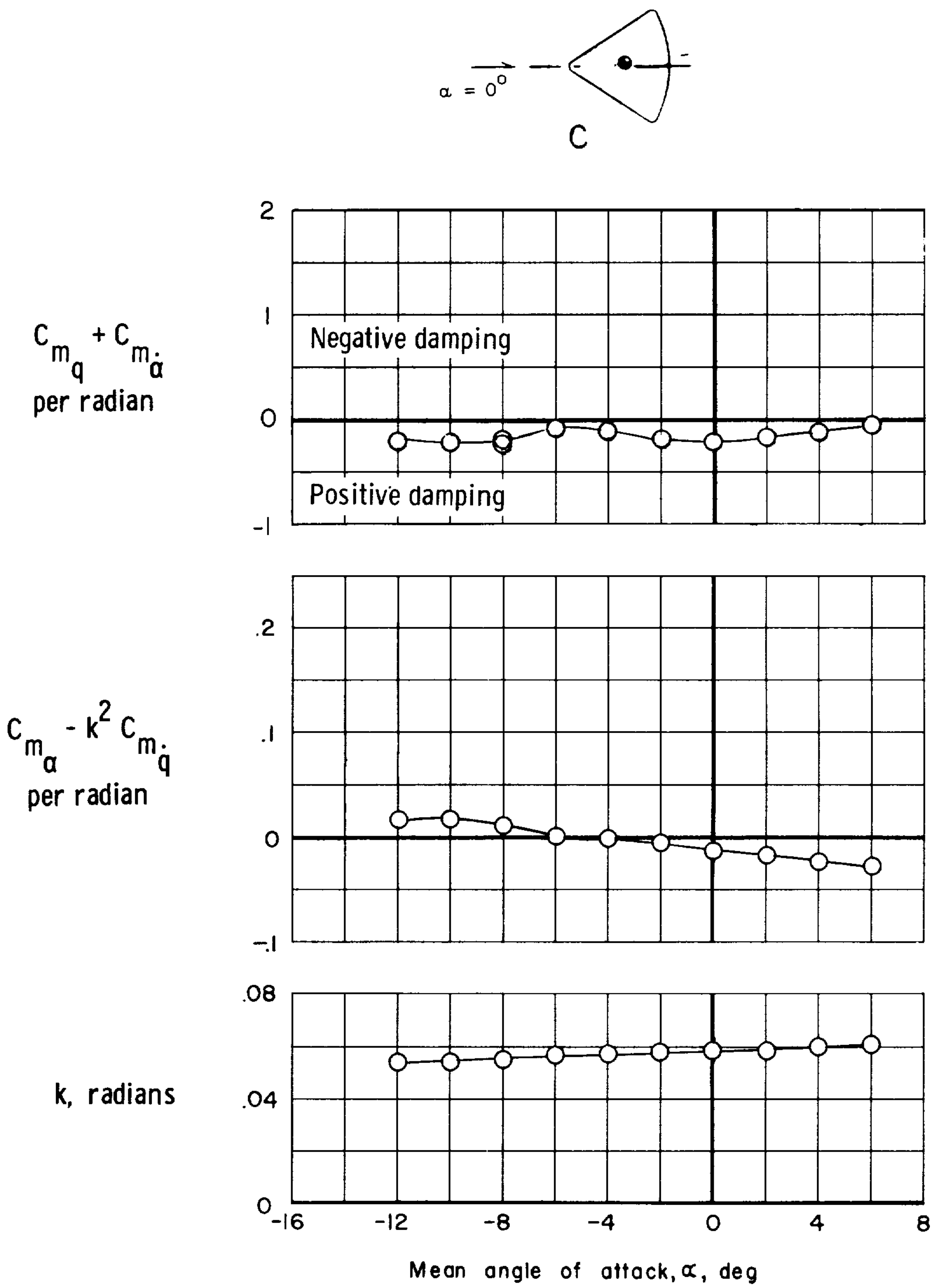
(a) $M = 0.30$; $R = 2.50 \times 10^6$.

Figure 2.- Variation of damping-in-pitch parameter, oscillatory-longitudinal-stability parameter, and reduced-frequency parameter with mean angle of attack for model of command module C with heat shield aft.



(b) M = 0.70; R = 3.49×10^6.

Figure 2.- Continued.



(c) $M = 0.90$; $R = 2.78 \times 10^{6}$.

Figure 2.- Continued.

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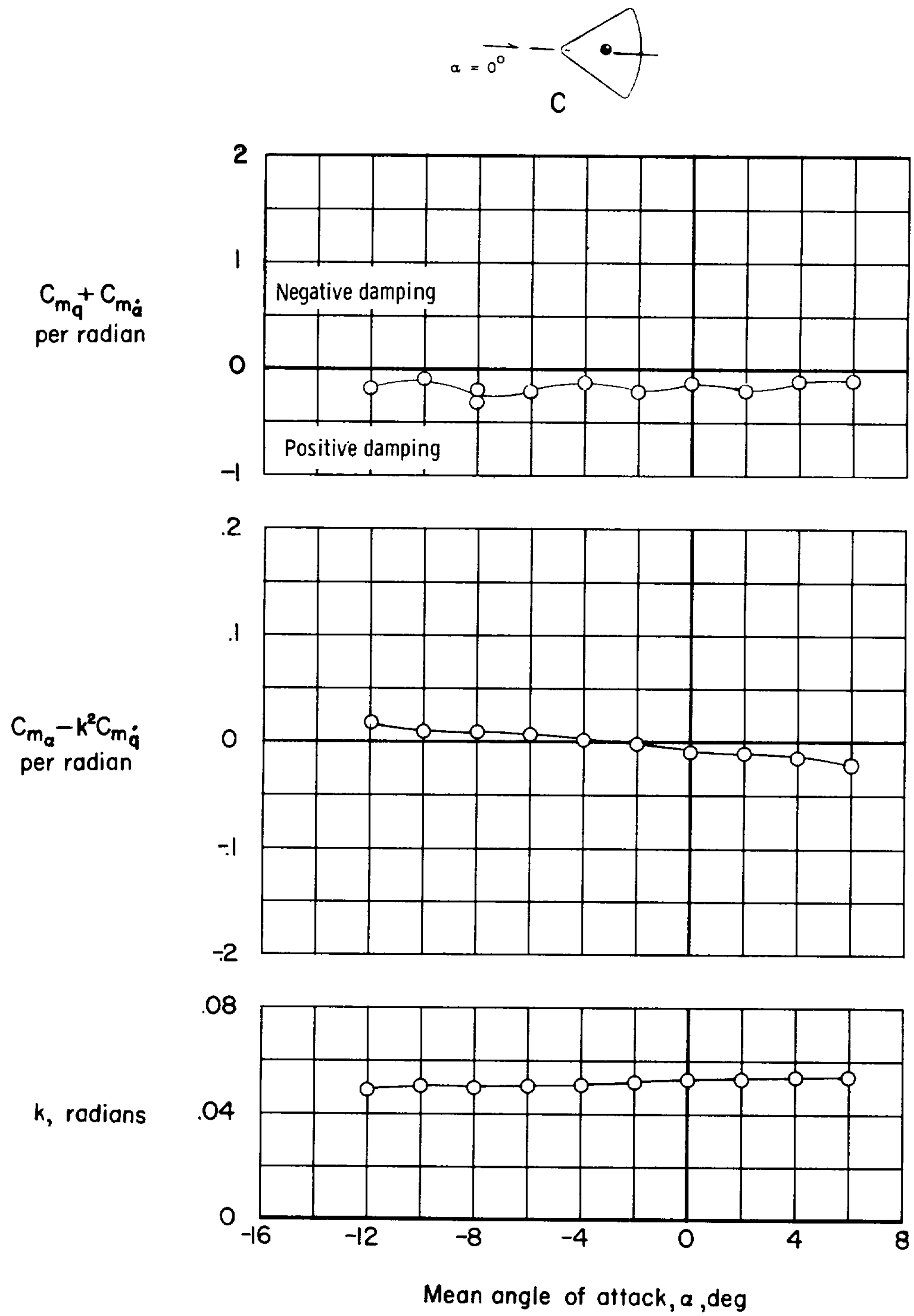
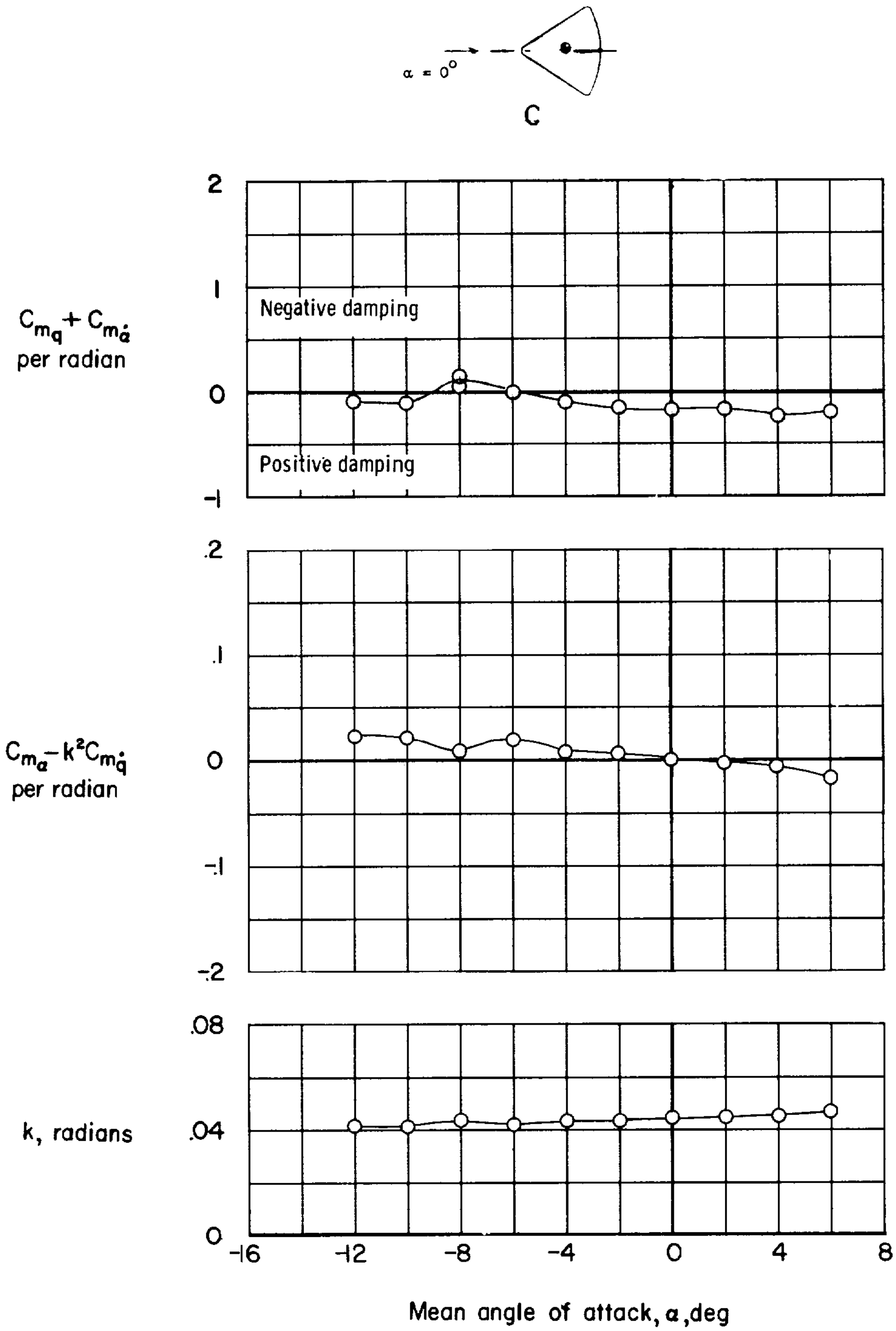


(d) $M = 1.00$; $R = 2.88 \times 10^6$.

Figure 2.- Continued.



(e) $M = 1.20$; $R = 2.96 \times 10^6$.

Figure 2.- Concluded.

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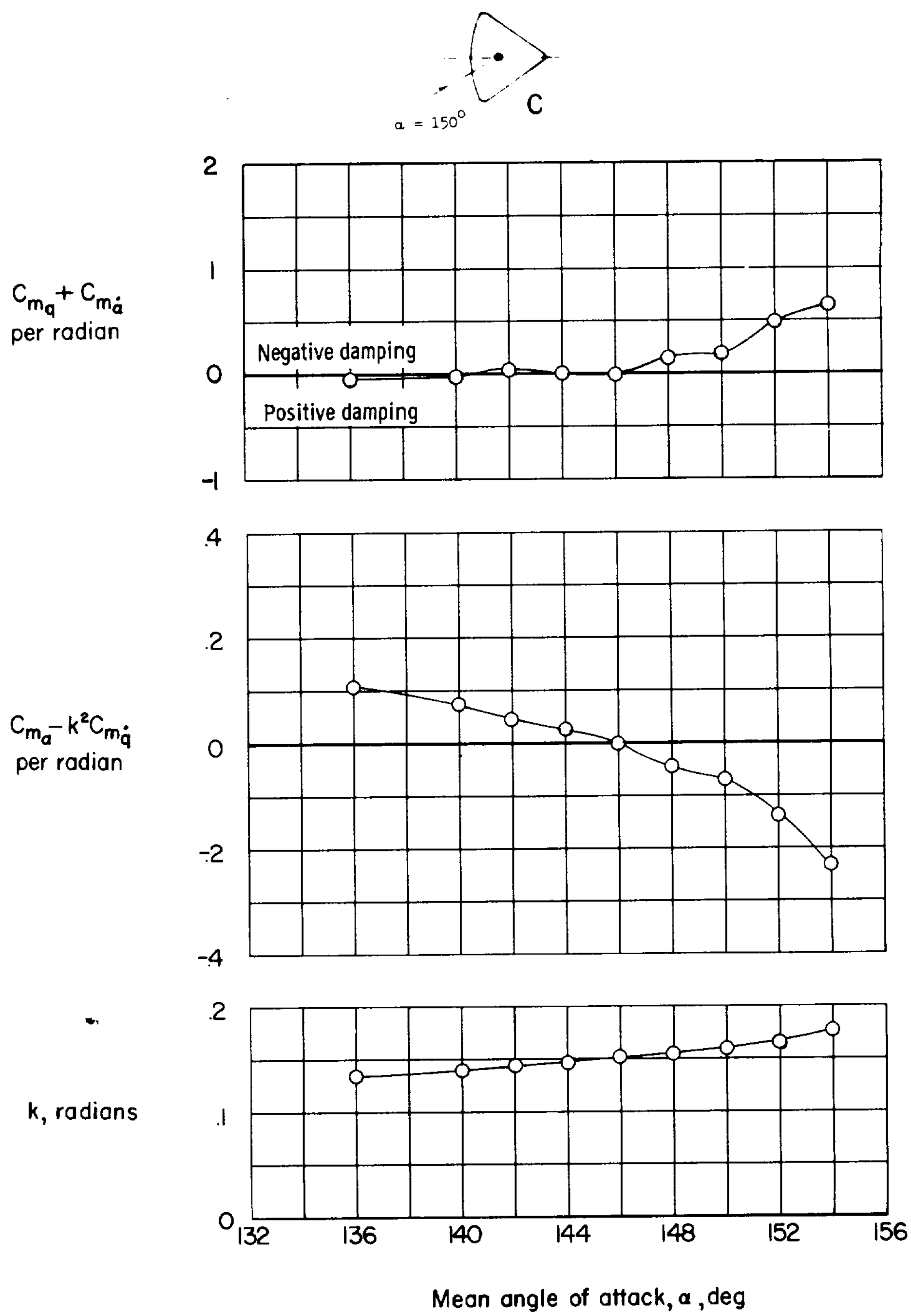

(a) M = 0.30; R = 2.50 × 10^6.

Figure 3.- Variation of damping-in-pitch parameter, oscillatory-longitudinal-stability parameter, and reduced-frequency parameter with mean angle of attack for model of command module C in a reentry attitude oscillated about its forward oscillation center.

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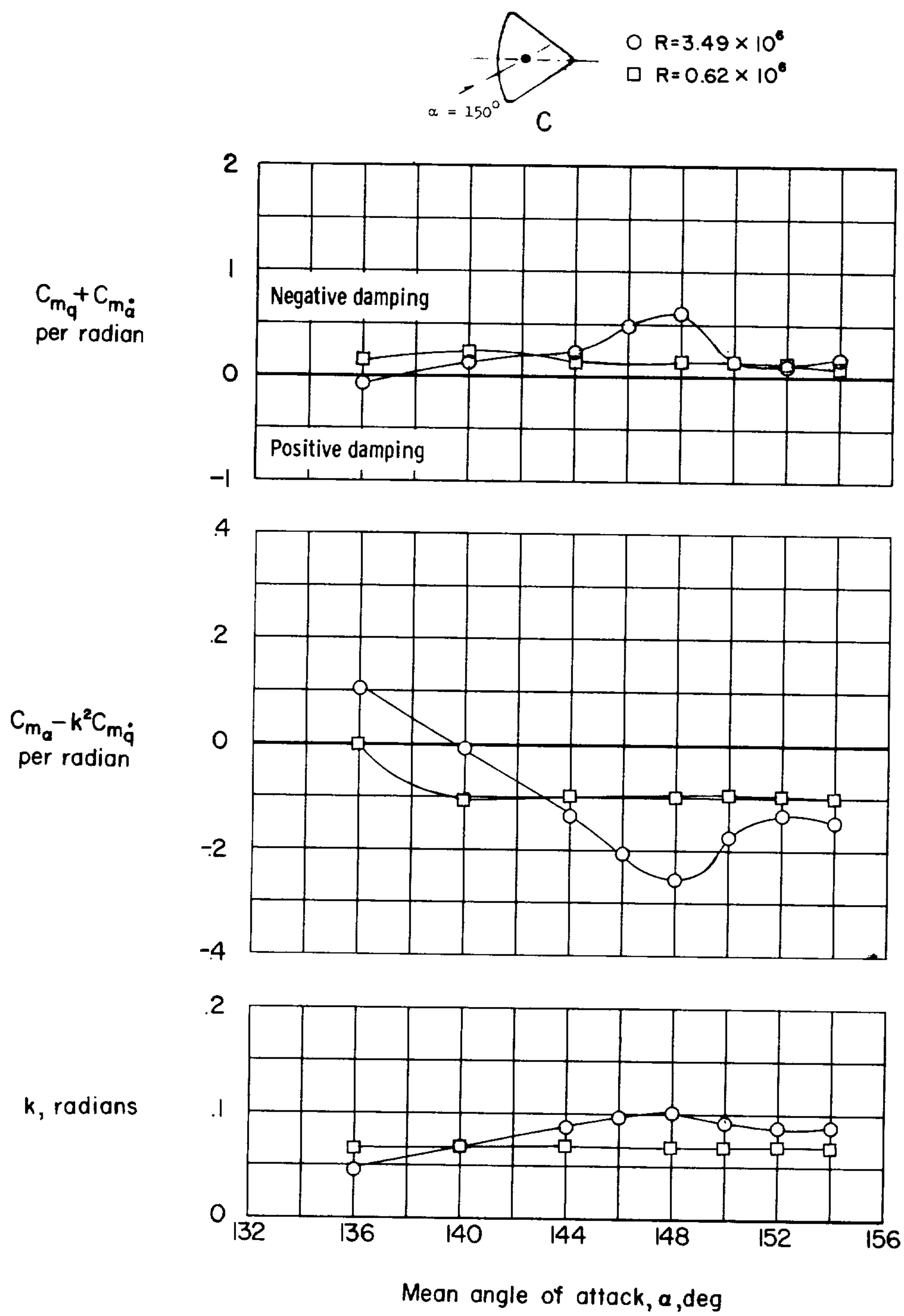

(b) M = 0.70.

Figure 3.- Continued.

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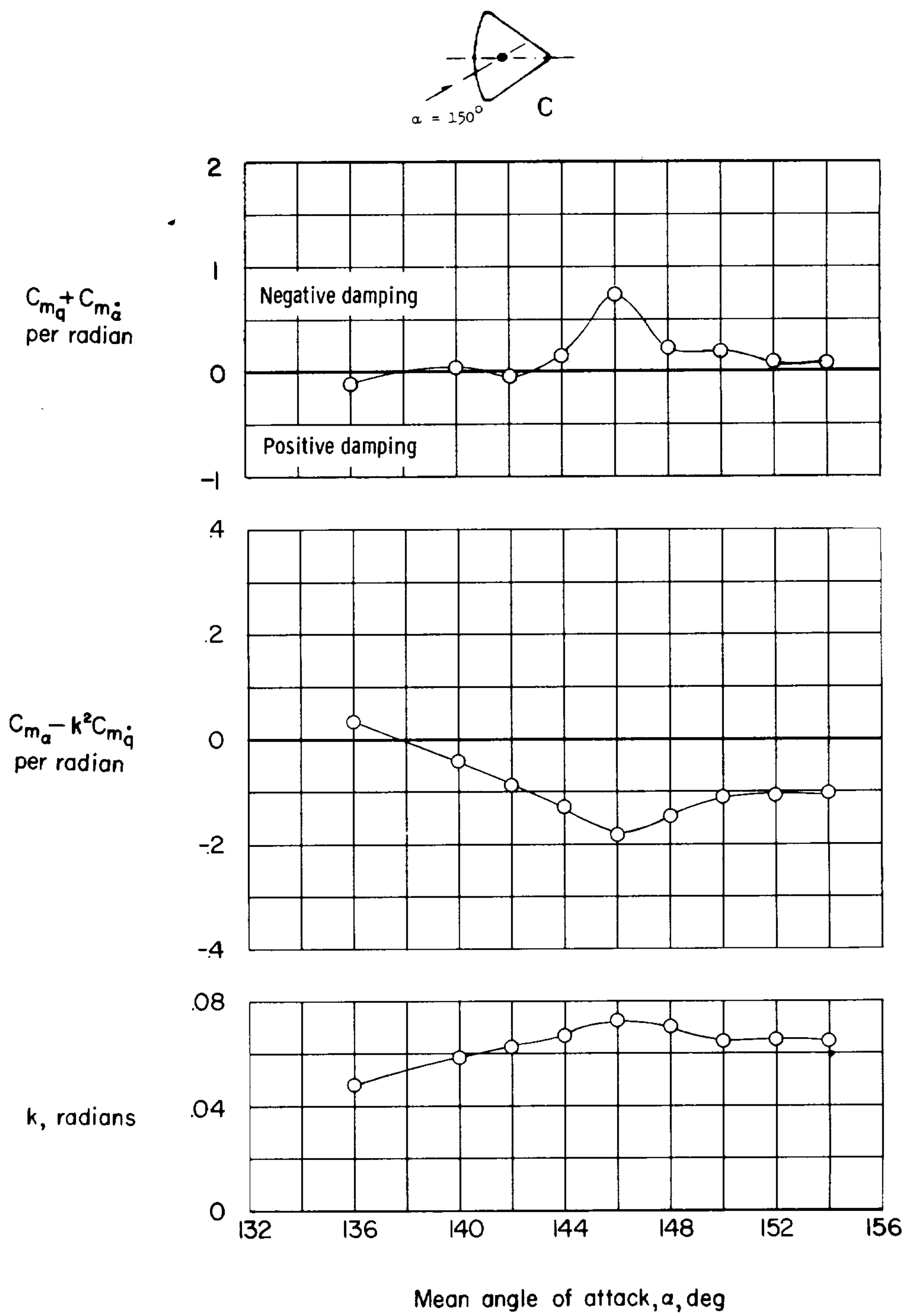

(c) $M = 0.90$; $R = 2.78 \times 10^6$.

Figure 3.- Continued.

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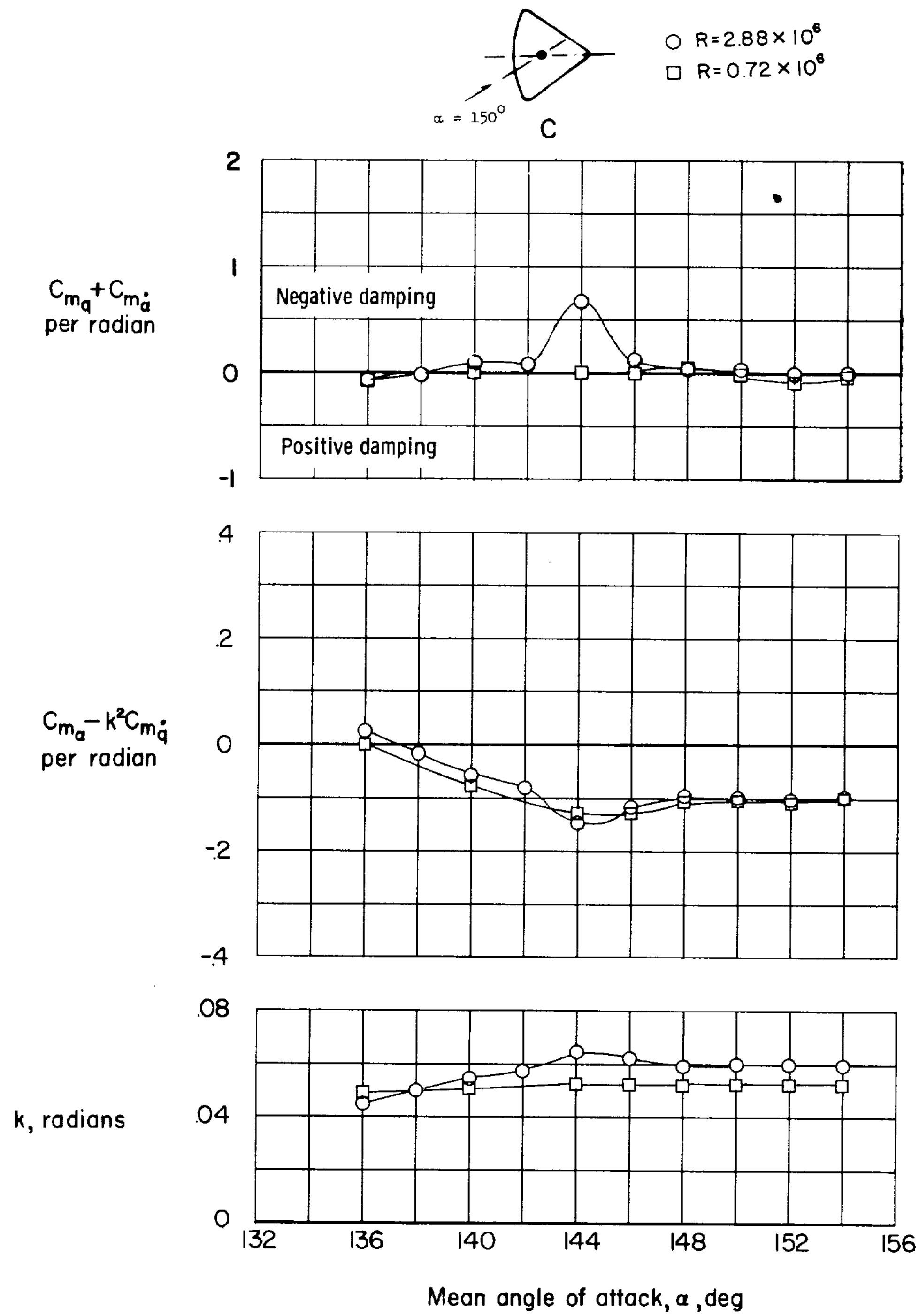

(d) M = 1.00.

Figure 3.- Continued.

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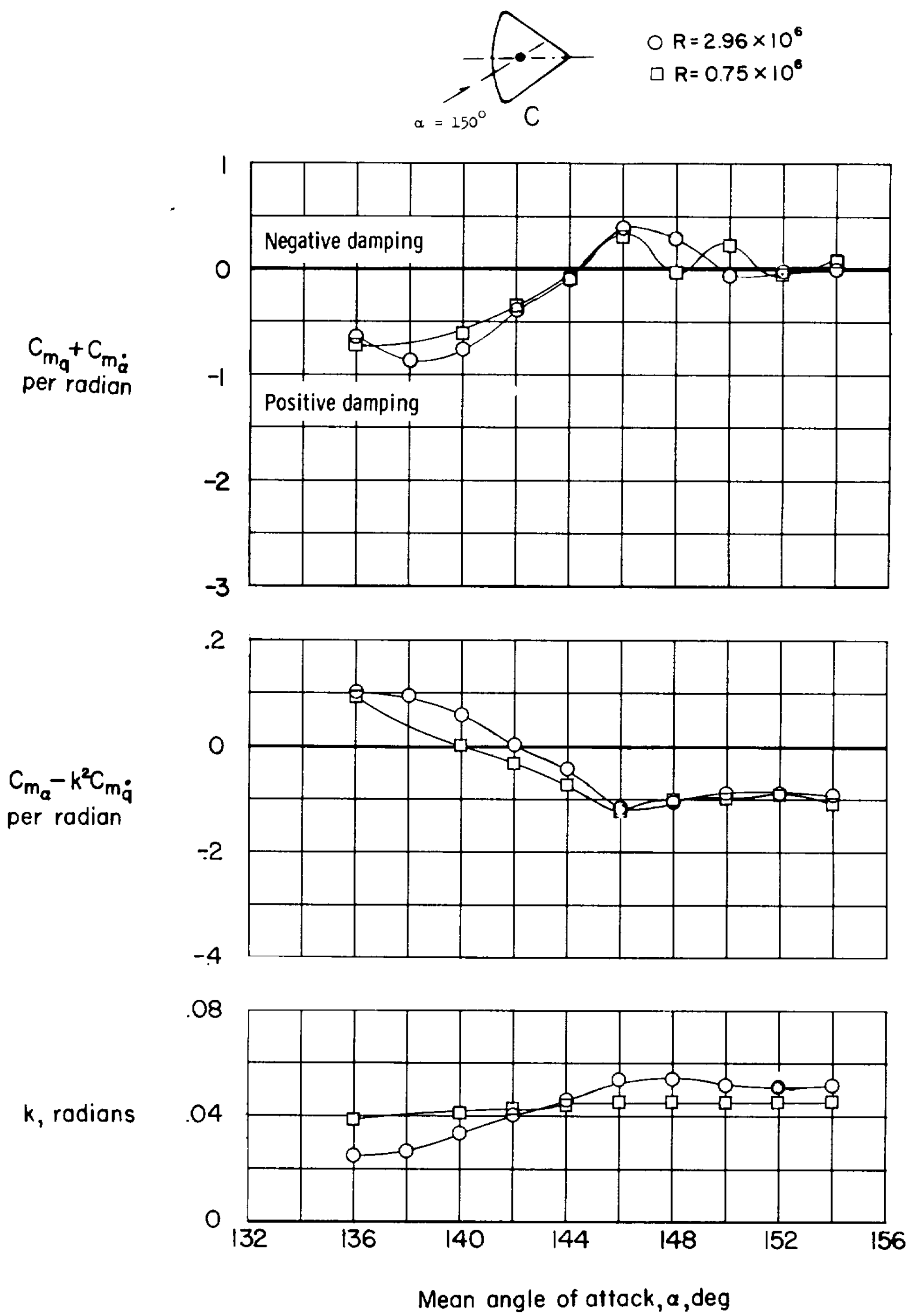
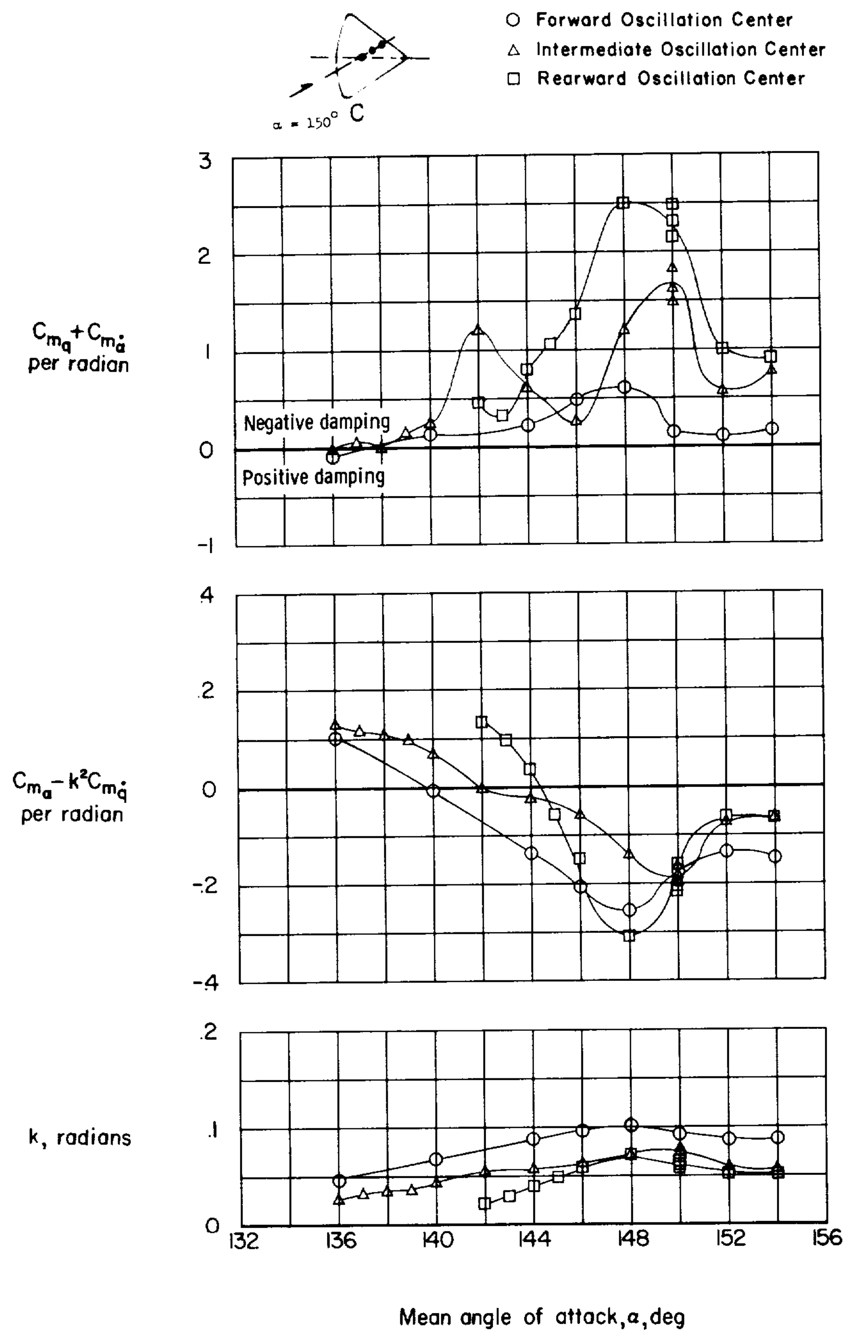


(e) M = 1.20.

Figure 3.- Concluded.



(a) M = 0.70; R = 3.49×10^6.

Figure 4.- Variation of damping-in-pitch parameter, oscillatory-longitudinal-stability parameter, and reduced-frequency parameter with mean angle of attack for model of command module C in a reentry attitude for three oscillation center positions.

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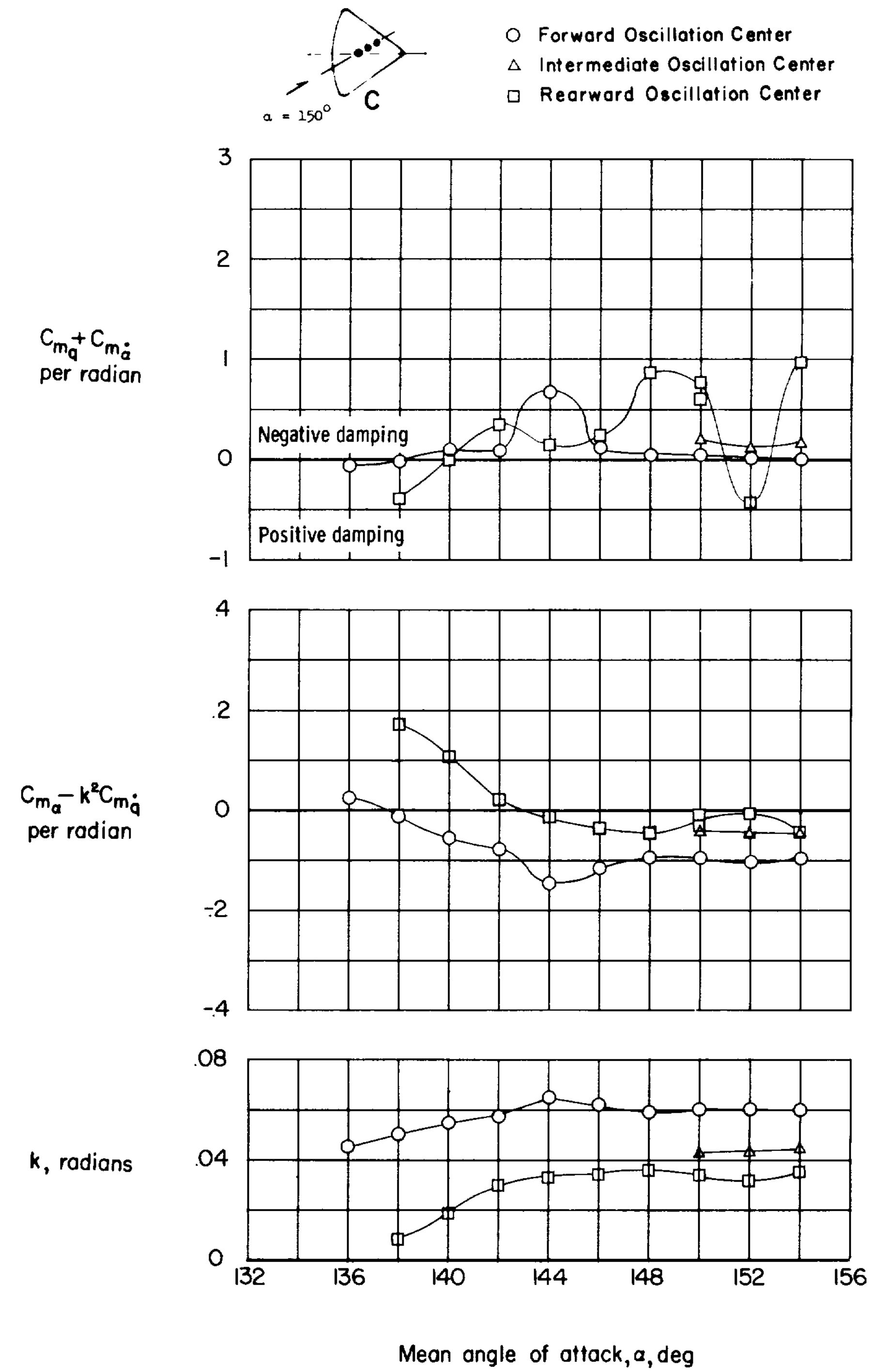
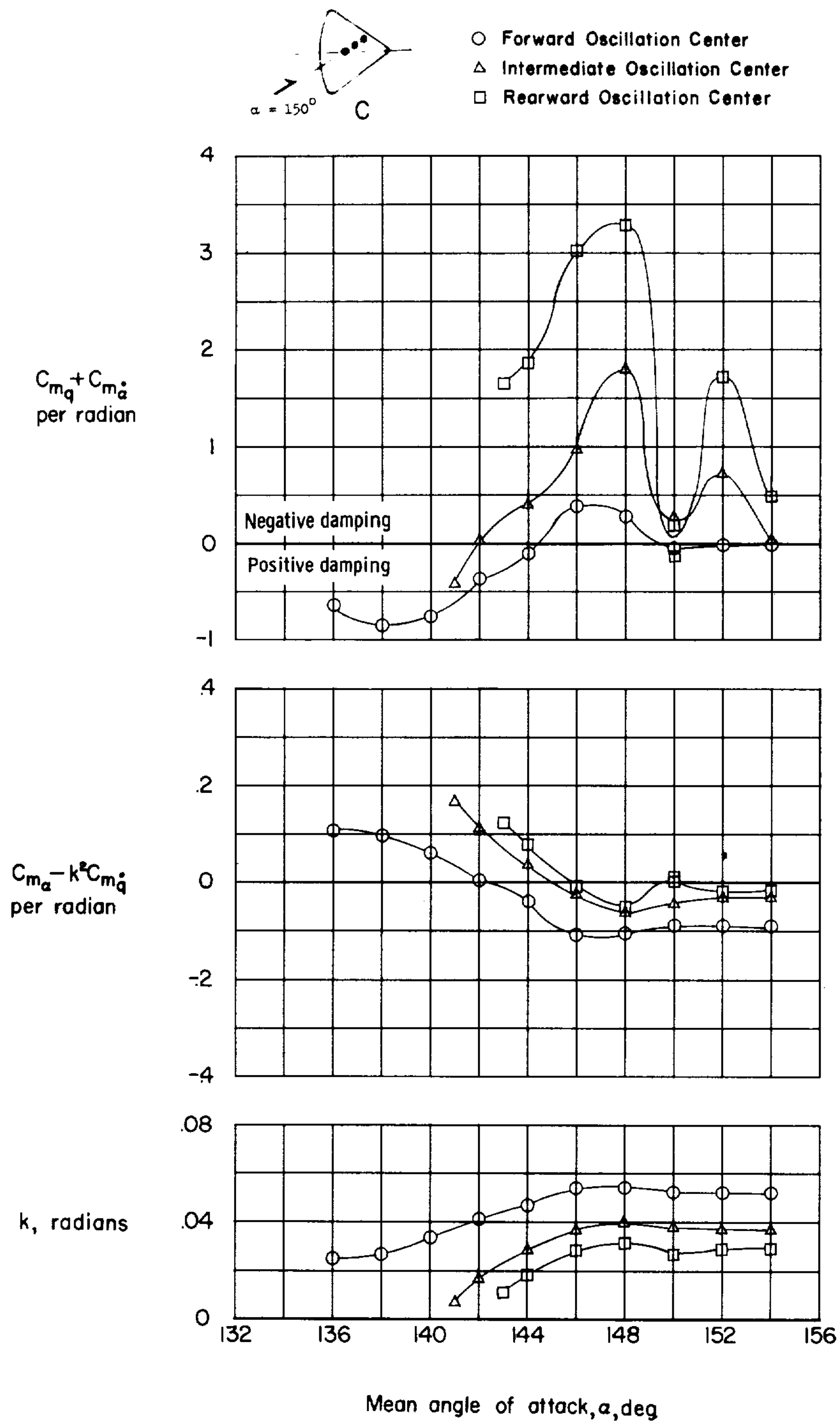


(b) $M = 1.00$; $R = 2.88 \times 10^6$.

Figure 4.- Continued.



(c) $M = 1.20$; $R = 2.96 \times 10^6$.

Figure 4.- Concluded.

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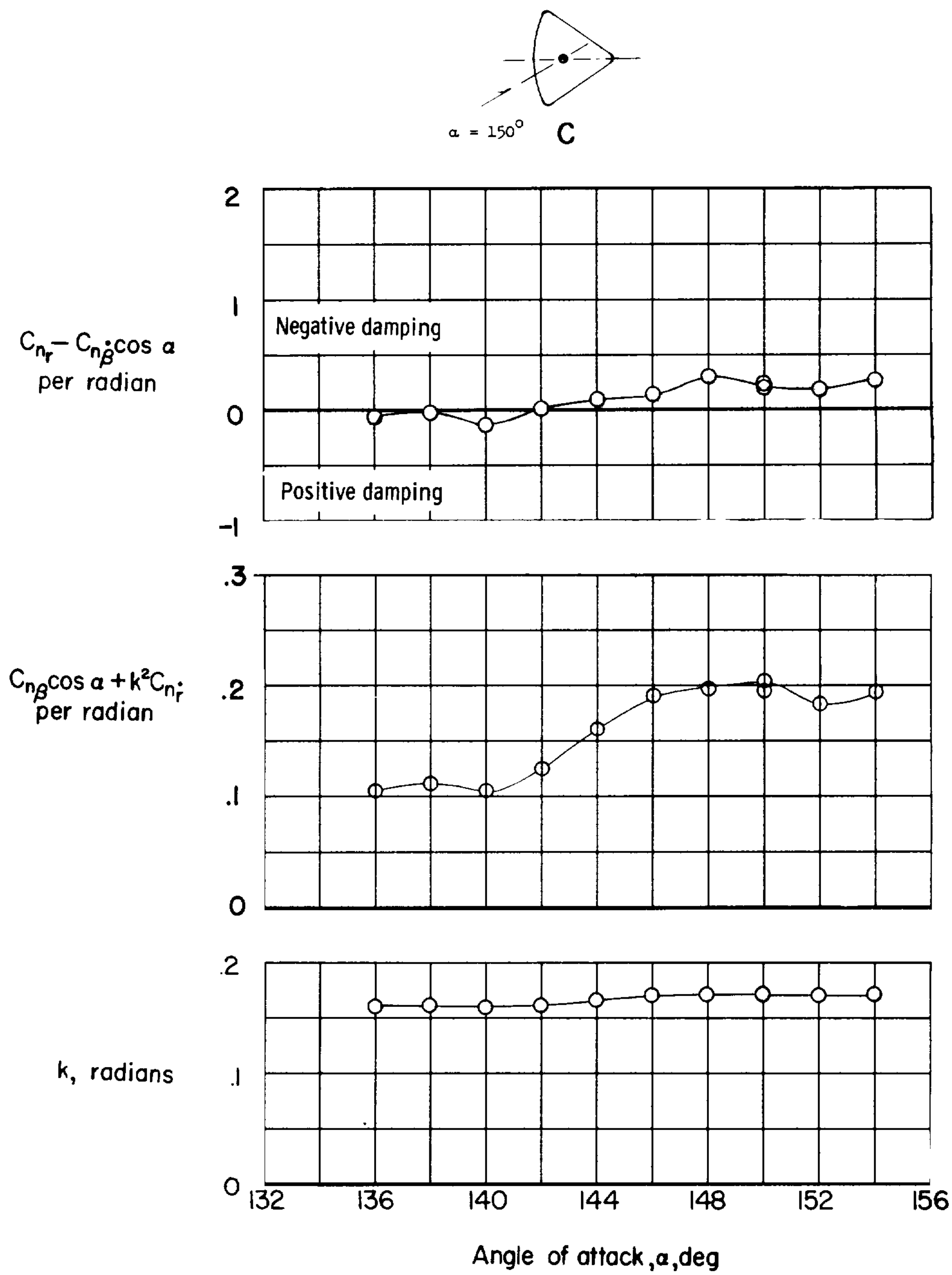
[redacted]



(a) $M = 0.30$; $R = 2.50 \times 10^6$.

Figure 5.- Variation of damping-in-yaw parameter, oscillatory-directional-stability parameter, and reduced-frequency parameter with angle of attack for model of command module C in a reentry attitude.

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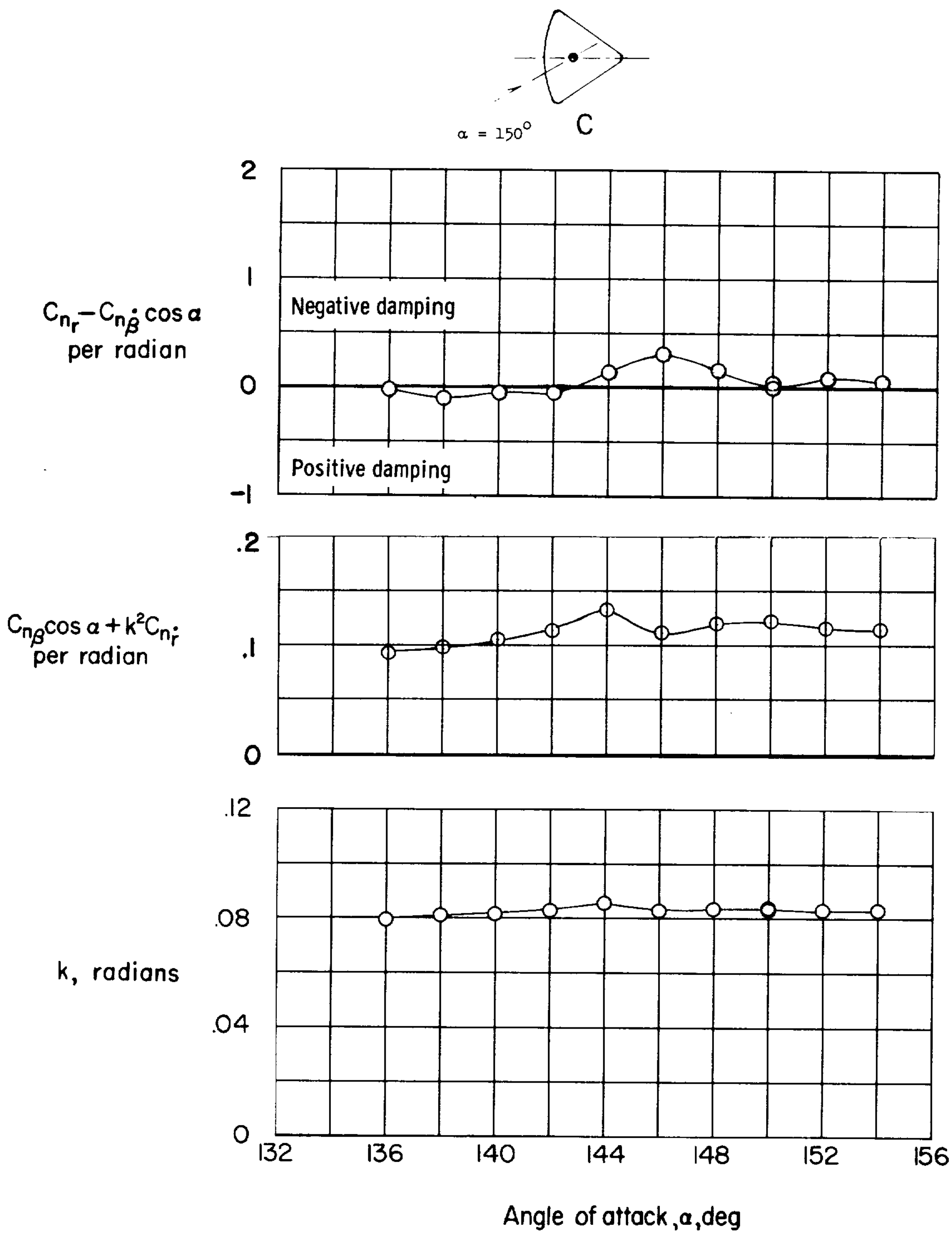

(b) $M = 0.70$; $R = 3.49 \times 10^6$.

Figure 5.- Continued.

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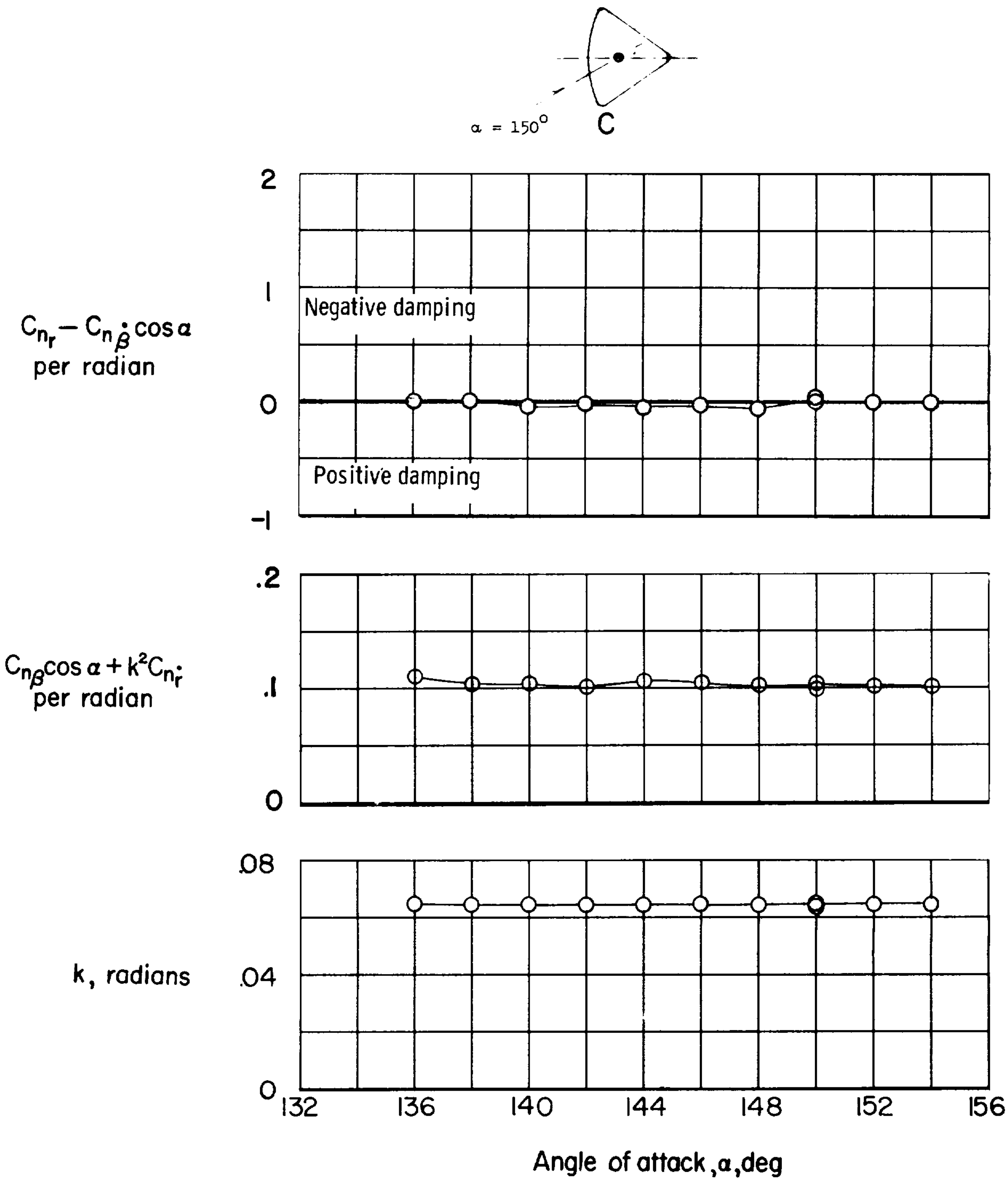
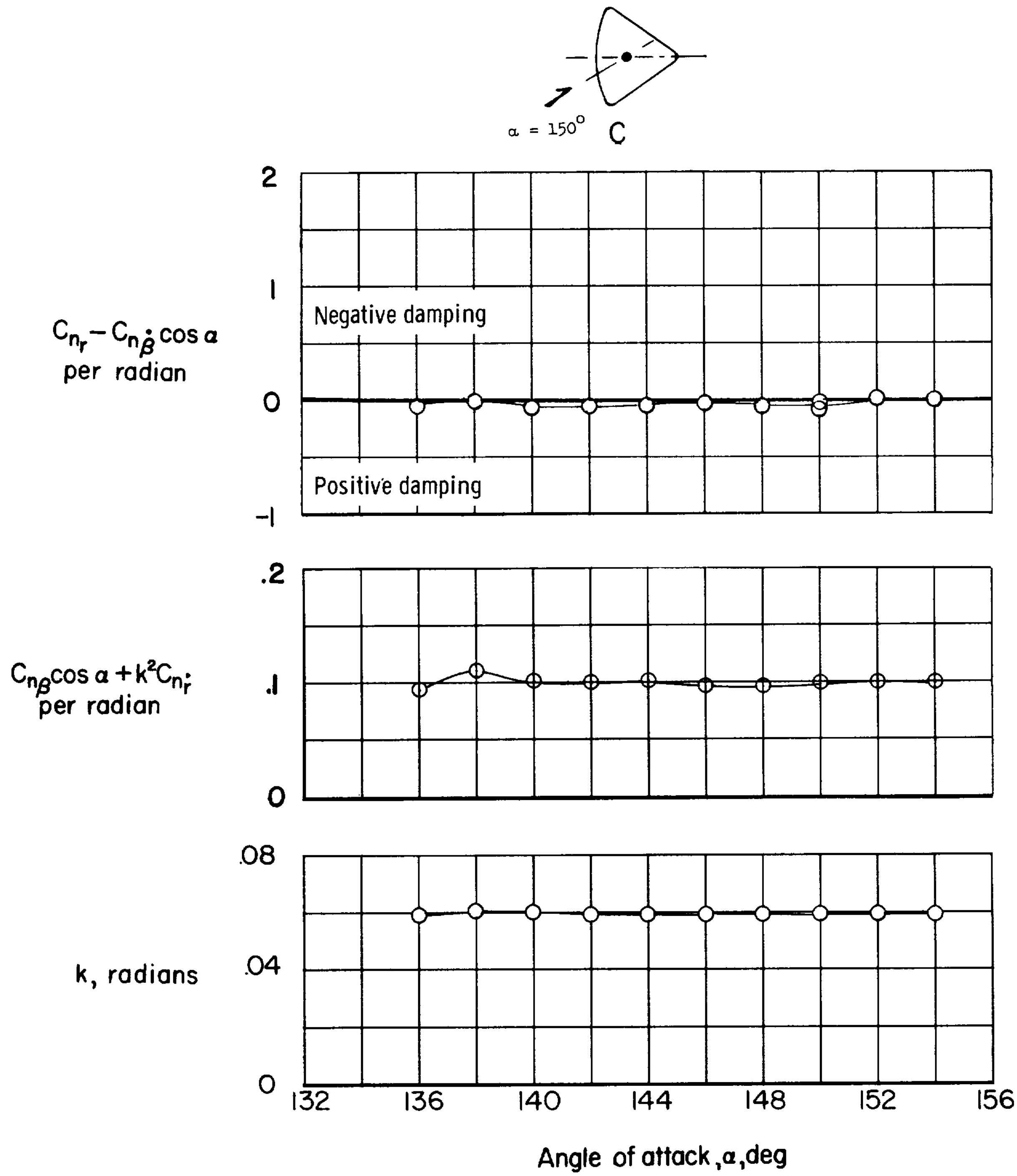


(c) M = 0.90; R = 2.78×10^6.

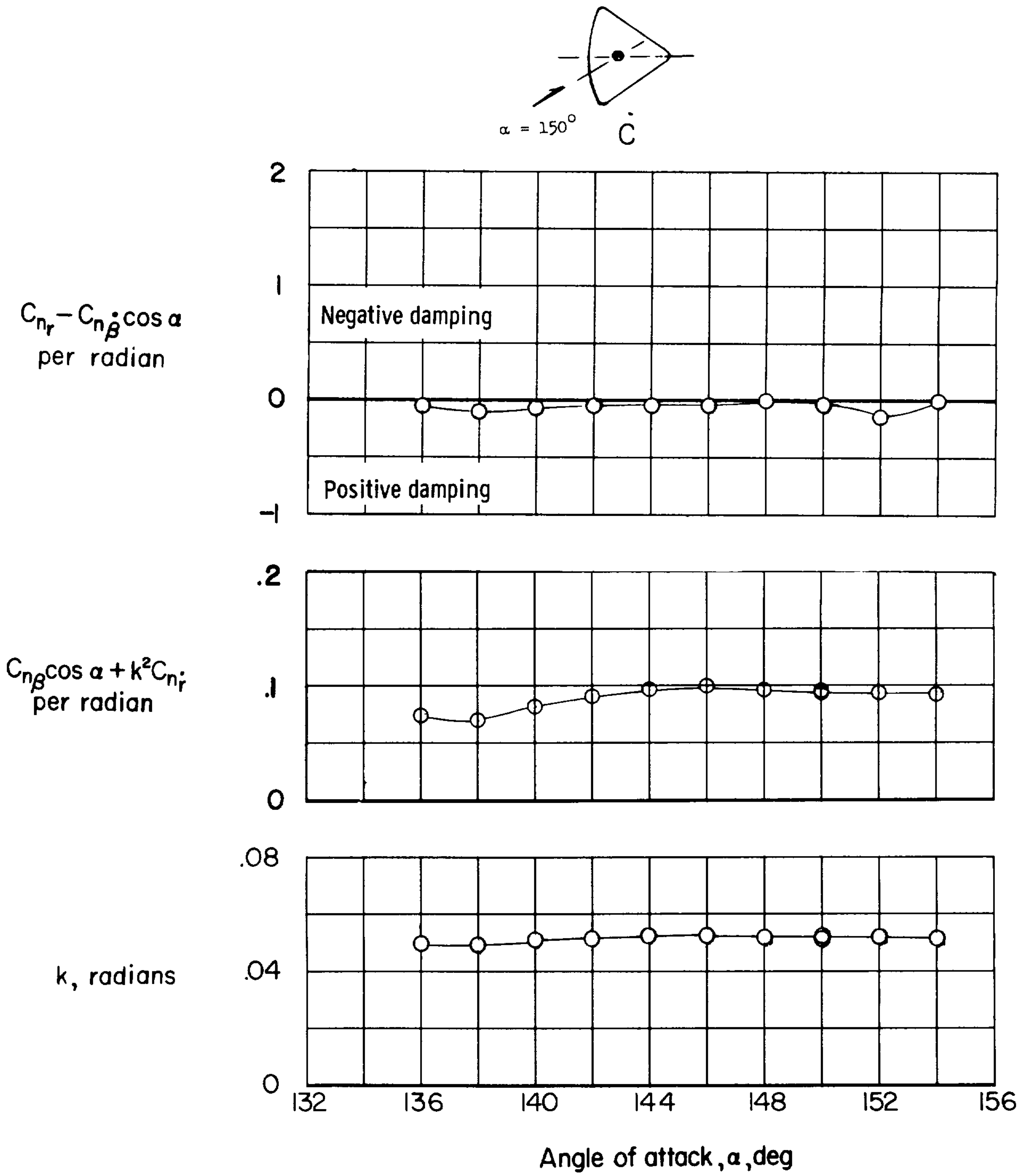
Figure 5.- Continued.



(d) $M = 1.00$; $R = 2.88 \times 10^6$.

Figure 5.- Continued.

[redacted]



(e) M = 1.20; R = 2.96 × 10^6.

Figure 5.- Concluded.

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